DOCUMENT RESUME

ED 178 336 / SE 029 271

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TITLE Using Computer Modeling in the Classroom to Examine Environmental Issues. A Teacher's Guide.

INSTITUTION Dayton Univ., Ohio.

SPONS AGENCY Office of Education (DHEW), Washington, D.C. Office of Environmental Education.
PUB DATE Jul 78
GRANT G007700611
NOTE 66p.

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Class Activities; *Computer Assisted Instruction; Computer Programs; *Computers; Electronic Data Processing; Environment; *Environmental Education; Environmental Influences; Interdisciplinary Approach; *Models; Science Education; Secondary Education

ABSTRACT

This guide provides instructions for the use of computer modeling to teach environmental studies or other subjects which may be difficult to teach. The computer modeling method described does not require input of quantitative data and does not produce a numerical model. The technique produces a qualitative model which portrays present or future situations and can be manipulated to aid student understanding of the concept under study. (Author/RE)

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1977-OEE # 611

Using Computer Modeling in the Classroom to Examine Environmental Issues

A TEACHER'S GUIDE

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U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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JULY, 1978

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ED178336

SE 029 271

Acknowledgements

Preparation of this Teacher's Guide was funded by Grant No. G007700611 from the Office of Environmental Education, Department of Health, Education and Welfare. The following persons planned and executed the pilot-test of the methodology:

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About the Teacher's Guide

MODELS IN YOUR CLASSROOM

This Teacher's Guide will show you how you can use one type of computer modeling in your classroom to teach environmental studies, or biology, or social studies, or almost any other subject that is complicated for your students to understand. Computer modeling is a scary term for some people, but it needn't be for teachers. After all, you use models frequently in your classes and probably don't give it a second thought: social studies teachers use globes, chemistry teachers use ball-and-stick models of chemical compounds, biology teachers use models of leaf cross-sections, English teachers diagram sentences, and so on.

COMPUTERS ARE DUMB, BUT FAST

Perhaps what bothers some people about computer modeling is the "computer" aspect, and not the "modeling" aspect. It is true that computers can be made to do very complex things, but in the final analysis they cannot do anything a human has not first told (programmed) them to do. The computer modeling method described in this guide is something you could do yourself, but it would take a long time, and in that sense the computer does it better, because it is capable of doing it faster. But there is no mystery about what is happening inside the computer, as you will see later.

QUALITATIVE AND QUANTITATIVE MODELS

First, let's get back to modeling. Models will be discussed at length in the opening section, but it is important that you recognize the difference between qualitative and quantitative models before we proceed any further. The difference between a mathematical model and the type discussed in this guide is that the first uses quantitative measurements and the second uses qualitative observations to build the model. When a scientist or mathematician thinks of a computer model, he often thinks of a computer program or formula that can use measurements or numerical data as certain variables to make numerical predictions for future situations. A well-known example is the model of population growth done by the Club of Rome and published in a book entitled The Limits to Growth. This controversial study took data on world population, growth rates, food supply and many other variables to predict a gloomy outlook for mankind within the next 100 years.

The computer modeling method described in this guide does not require quantitative data for input, and it does not produce a numerical model. It does produce a qualitative model that reflects the accuracy of the modelers' observations; that can be used to describe a present or future situation; and that should aid student understanding of the situation under study.

The computer modeling method described in this guide is known as Interpretive Structural Modeling (ISM). It was originally developed for policy analysis and other decision-making types of activities. For instance, the Dayton City Commissioners have used this computer-modeling method to describe a desirable 10-year future for Dayton. Other examples are included in Appendix A.

Educators who know of the method's success in such activities saw that it had many features that might make it a useful teaching tool. The University of Dayton conducted a pilot project in Chaminade-Julienne High School, Dayton, Ohio, to see if the method was workable in the classroom. The study was funded by the Office of Environmental Education. The instructions contained in this guide are based on the methods we used to teach a Biology teacher and a World Problems teacher how to adapt ISM to their courses. Those methods have since been modified in response to student reaction to computer modeling and the teachers' suggestions for improving the method for educational use.

I. INTRODUCTION TO MODELING

Models Defined

A model is an image or simplified representation of something in the real world. Every time we describe an object or a situation, we are really constructing a model. A model includes (1) our observations or perceptions about the thing, that is, about its parts or features, and (2) our beliefs about how the parts are related.

WHAT IS A MODEL?

A model is a simplified version of something. To be useful, it does not have to include all the details about the thing it represents; instead it includes only those parts that are seen to be important for a particular purpose. Therefore, a model makes it easier to think about and work with complicated situations. A globe, which is nothing more than a model of our world, need not show every stream and town on the face of the earth. Major features of the continents and oceans suffice to make a globe instructive.

MODELS AND EDUCATION

It is the simplified aspect of models that makes them so useful for teaching. Relatively less important characteristics of a situation or object can be set aside while students and teacher focus on the basic features. Once those are mastered, a more complex or more realistic model can be grasped by the students.

For example, when children first learn the alphabet, they are taught to recognize block-style letters having the basic letter shape. Then they learn to read script letters, and later words composed of block or script letters. When they first learn about plants, they learn to recognize them by shape of leaf or color of flower. Later they learn about the cellular structure of leaves and the parts and function of a flower.

Types of Models

Mental Models

All of us have mental models about the things around us. A mental model is the "picture" of reality a person has in his or her head. This "picture" is our understanding of (1) a tangible object, (2) a material situation, or (3) an intangible situation.

MODELS OF TANGIBLE OBJECTS

For instance, if you were given directions for driving from the University of Dayton to the Courthouse Plaza downtown, you would create a mental model of the street corners, traffic lights, and buildings that you pass to get there. The directions may lead you to create a mental model that does not coincide with what you observe in making the drive. If there is enough discrepancy, you may never get there by the directions alone. All the same, your mental model would represent material reality.

MODELS OF INTANGIBLE OBJECTS

As an example of a less tangible situation, most people have their own mental "picture" of something called "the energy crisis." This picture probably includes ideas about:

- causes and effects of the energy crisis
- how people's lives will be changed with various energy alternatives
- what people should do about energy

A person's mental model of the energy crisis influences his or her beliefs and behavior with respect to energy issues.

Clearly, people's mental models of the energy crisis will be different. Depending on their education and experience, people will think of different parts of the problem and different ways to explain the situation.

PROBLEMS WITH MENTAL MODELS

This brings us to the problems with a mental model.

1. A mental model may be inaccurate or incomplete. The facts on which it is based may be false, the underlying assumptions may be invalid, and important factors may have been overlooked.

2. A mental model may be inconsistent. Since the model exists in a person's mind only, it may vary from one situation to the next.

3. In a mental model, it is difficult to keep the pieces straight, which accounts for the inconsistency referred to above. There are often too many facts for a person to remember all at once in any meaningful way.

4. It is difficult for a person to communicate the mental model to other people. Returning to the energy crisis example, it would probably be difficult for you to describe accurately all that you mean when you refer to the energy crisis, especially if you were restricted to words. Clearly, we need more formal models to express our concepts.

Formal Models

Mental models are the starting point for all other types of models that we make. Starting with our rough mental "picture," we often find it easier to communicate our ideas by using models built of words, numbers, cardboard, plastic pieces, etc. Model cars and airplanes jump to mind when we think of tangible formal models. However, a food web constructed by an ecologist and showing on paper by means of blocks and arrows what a biological organism eats and what in turn eats it is just as valid a formal model.

PHYSICAL REPRESENTATIONS OF REALTIY

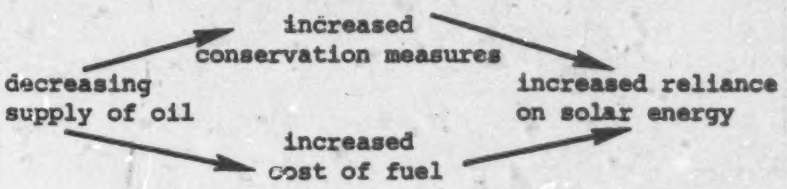
Interpretive Structural Models

The method described in this guide is intended to help you as a teacher help your students to construct a type of formal model known as an interpretive structural model. Don't let that long name bother you; it is easily explained if it is taken in parts. The final product of a class exercise conducted with this method is a model in the sense discussed above--it represents reality. It is a structural model in that its creators (in this case, you and your students) have looked at the parts of a problem or issue and the way in which those parts are related, and have drawn a diagram to represent the structure that results from the relationship among the parts. It is an interpretive structural model because it reflects its creators' interpretation of reality. Thus the process by which one creates such a model is called Interpretive Structural Modeling, or ISM for short.

THE MEANING OF THE TERM

AN EXAMPLE

Now, one student could write out everything he thinks is a cause or result of the energy crisis, and every way that he thinks our lives will change as a result of it, and everything he thinks should be done about it. If he were then to draw arrows from one cause to all its effects, a small part might look like this:



where the arrows represent causality, and lo and behold! he would have created an interpretive structural model without even knowing it.

LEARNING AS A GROUP EFFORT

To create his interpretive structural model of the energy crisis, the student had to rely on the facts at his command and his adolescent understanding of world economics, government intervention, consumer attitudes, etc. His model is influenced by his own biases as well. As an extreme example, a student whose mother is a nuclear physicist might produce a model quite different from that of a student whose father works for an oil company, and the ecologist's daughter's model might be different from either of the others. A knowledgeable judge (like yourself) who makes a conscious effort to set aside personal biases would see realistic aspects in all three models. The point is: students stand to learn from one another as well as from you, the teacher. An ideal form of learning would enable and encourage this information transfer to take place from student to student, from teacher to student and even, hopefully, from student to teacher.

BENEFITS OF ISM

That is where model building, and in particular, Interpretive Structural Modeling, comes into play. When people build a model together, they have a chance to

- share their ideas
- improve their understanding of the situation being modeled
- correct false impressions, and
- create a more accurate and useful model of reality than they could have created by themselves

A good model improves our understanding of a situation and helps us communicate that knowledge to others.

It is appropriate to use Interpretive Structural Modeling when the issue or problem under study can be broken down into its component parts, i.e., the factors that together describe the situation. As the class systematically examines how the factors are related to one another, the essential parts of the issue become clearer and the relationships among them are made explicit. The computer is used to simplify the process.

WHEN IS ISM APPROPRIATE?

How the Computer is Used

For purposes of discussion, let's stick with the energy crisis as an example. If you want your class to study the energy crisis, you might well consider the problem from the standpoint of cause and effect. If the class were then to list all the causes and effects that they could think of, they would produce what is called an "element list" in the language of Interpretive Structural Modeling.

ELEMENTS

The next step would be to consider how each of the elements is related to each other element. This is done by selecting a relationship by which to examine them. Since the class is considering causality, you might well choose the relationship (which is always posed as a question): "Does Element A cause Element B?" So, in our imaginary situation, the symbols A and B might be replaced by the Element 1, decreased supply of oil, and Element 2, increased conservation. The question then would read: "Does decreased supply of oil cause increased conservation?"

RELATIONSHIPS

The answer to each question must be "yes" or "no," depending on what the class decides by majority vote. All possible pairs of elements are compared by this method, and this is where the computer comes in. The computer at the University of Dayton is programmed so that, if an element list and a relationship in the form of a question are fed into it, it will then substitute each possible pair of elements into the question and print the question on paper or on a TV monitor. So the first reason for using the computer is that it writes out each question for you, and saves you from having to put each pair of elements on the blackboard.

The second reason is that the computer reduces the number of questions that the class must answer. For example, if the class decides that "A relates to B" and that "B relates to C," the computer, by a principle known as "inferential logic," has already been programmed to infer that "A relates to C," and it will not ask that question. The manner in which it is programmed to do this is somewhat complex (but

THE COMPUTER SAVES TIME

it is included in Appendix B for those readers who are interested). For purposes of the immediate discussion it is not important that you know more than that the computer does in fact, by inferential logic, reduce the number of questions about paired elements that the class must answer.

In a still simpler example, Figure 1 shows an element list, a relationship, and the full text of the question, exactly as it is posed by the computer. (The example of Presidential chronology is intentionally simplistic; our reason for selecting it is that you not be distracted by the content of the example, but that you see exactly what the computer is doing, which is nothing more than filling in the blank.)

A SYSTEMATIC WAY TO MAKE A MODEL

The computer provides a systematic method for studying all possible pairs of elements (minus the pairs whose relationships it infers). As a result, you can produce a model at the end of the modeling exercise that reflects all the answers that the class recorded in the computer.

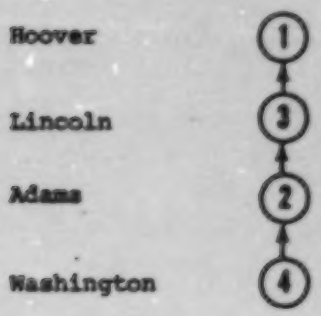
This is made possible by a summary of the information that can be printed on paper (computer printout) or displayed on the TV monitor at the end of the session. The following shows one such summary of the Presidents' chronology problem begun in Figure 1.

Computer Printout	Comments
LEVEL NO. 1	
2	"2" is the element number for Hoover.
LEVEL NO. 2	
3 → 2,	The arrow stands for the relationship. This line would be read "3 served as president before 2."
LEVEL NO. 3	
1 → 3,	
LEVEL NO. 4	
4 → 1,	

Computer Printout		Comments
1.	/R1	This is how you type the relationship. Lines beginning with a slash are typed by the computer, and you type a response.
2.	DID	
3.	/R2	
4.	SERVE AS PRESIDENT BEFORE	
5.	/R3	
6.	?	
7.	/EL 1	This is how you "tell" the computer what your element list is.
8.	ADAMS (1)	
9.	/EL 2	
10.	HOOVER (2)	
11.	/EL 3	
12.	LINCOLN (3)	
13.	/EL 4	
14.	WASHINGTON (4)	
	1st ELEMENT # ?	The computer "asks" what element number you want to start with. Here the operator picked 1. He could have picked 2,3 or 4. It then "asks" for another element number. Once the computer operator answered 2, the computer substituted Element 1 (Adams) and Element 2 (Hoover), as instructed above, in the relationship. The operator typed "Y" to indicate that the answer to the question is yes.
	*1	
	NEW ELEMENT NUMBER ?	
	*2	
	DID	
	ADAMS (1)	
	SERVE AS PRESIDENT BEFORE	
	HOOVER (2)	
	?	
	*Y	

Figure 1. Sample Computer Printout for ISM Exercise

The numbers are those originally assigned to each element in the element list in Figure 1. The arrows represent the relationship "served as President before." The diagram below shows the interpretive structural model based on that information coded as numbers.



Using the information as printed out above, you can draw a model like this to represent who preceded whom.

What Happens During an Interpretive Structural Modeling Exercise?

The physical setup for a modeling session is described in detail in Section II; for now you need only concern yourself with the three most important components: the classroom, the computer terminal, and your class. Imagine a room with about twenty desks or chairs arranged in groups of five, with each group facing each other and a TV monitor. In an inconspicuous corner of the room is a computer terminal, which looks very much like a portable typewriter, except it has a cradle on top that holds a telephone receiver. The computer itself is at the University of Dayton, but it is connected to the classroom by a telephone line. A trained technician directs the computer by typing in information provided by the class. You could learn to do the same thing, but that would go beyond the scope of this guide.

PREPARE FOR MODELING

The entire process, from start to finish, proceeds as follows. You already have a topic that you think lends itself to this computer modeling method of study, so you break it down into specific areas for your students to research individually or in teams. When you ask your class to develop a list of elements that contribute to the problem or issue, the list should reflect previous study by the students. During the class discussions in which the element list is generated, you can introduce new material through lectures or out-of-class assignments.

The next stage of the modeling involves the computer, which prompts the class to systematically examine the relationship between the elements two at a time. The students' conclusion about the relationship is recorded in the computer's memory bank. After an initial model has been developed, the class is free to amend it as necessary to incorporate new insights gained from the modeling experience. This amending can be done manually or with computer assistance.

ENTER: THE COMPUTER

Once the class has produced a model, they can explore and test the implications of the model. This includes examining the assumptions implicit in the model, and even testing alternative assumptions. Current policies and practices can be studied in light of the model.

STUDY THE FINISHED MODEL

Each of the activities of generating an element list, choosing an appropriate relationship, amending the model, etc., is discussed at length in Section II. Our immediate concern, now that you have a general (if somewhat confused) notion of ISM, is that you see its value in your classroom.

Interpretive Structural Modeling as a Teaching Method

Interpretive Structural Modeling has several characteristics that make it uniquely suited as an instructional tool. Its use results in the following benefits[1]:

- improved class discussion
- students have a better understanding of a problem - its components and their relationships
- student discussion results in a documented, tangible model
- students gain an increased appreciation of formal problem-solving techniques
- students' ability to deal with complexity is enhanced

[1]Adapted from Robert J. Waller, "Interpretive Structural Modeling: Reflections on Its Current State and Some Speculations about Its Future."

FOCUSED DEBATE

Improved Class Discussion

In carrying out an Interpretive Structural Modeling session, the class discussion centers on the relationship between elements. The beauty of the method is that, though the list of elements may be long, they are considered only two at a time. By the time all possible pairs have been considered (minus those pairs whose relationship the computer is programmed to infer), a structural model has been produced.

The computer assists the class in three ways. First, it acts as a bookkeeper, keeping track of the "yes" and "no" answers given by the students in a majority vote in each pairing. Secondly, by inferential logic, it picks a way of presenting the next comparison question so as to minimize the number of questions that need to be answered, hence saving time. Finally, the computer analyzes the information to allow a model to be drawn illustrating the relationships among the elements.

Better Understanding of the Topic and Its Structural Relationships

A PICTURE MEANS MORE THAN A LIST

Without the benefit of Interpretive Structural Modeling, you may find you are extremely limited in your approach to class consideration of a complex problem. You can mention several factors in a lecture or class discussion for your students to consider; but both you and they are limited by the number of information items that a person can remember at any given time. You can use the time-honored method of writing a list of factors on the blackboard to aid student memory and to indicate priorities; however, this approach does not handle interelationships well. Yet another approach involves drawing a network of relationships with boxes and directed arrows; but without inferential logic, this leads to an awkward schematic diagram that does more to confuse than to clarify if the problem is complex. In contrast, the diagram produced by Interpretive Structural Modeling organizes and simplifies information and processes that are too complex to be conveyed easily by words.

Documented Model

THE PROCESS IS IMPORTANT

In addition to the pictorial model itself, one of the products of an Interpretive Structural Modeling exercise is a textual documentation of the discussion that took place in deciding on the relationships among the elements. The students themselves can prepare the documentation as the modeling session progresses. During the course of the ISM exercise, you can direct individual

study and lead class discussion, guiding student input and reflection. You can introduce factual course content prior to the modeling session or intersperse it throughout. The documented model provides a record of the facts, the process, and the product.

Increased Appreciation of Formal Problem-Solving Techniques

It is unlikely that most high school students are exposed to any formal problem-solving techniques other than the scientific method. In this respect, using Interpretive Structural Modeling represents an innovative approach to secondary education.

Enhanced Ability of Students to Deal with Complexity

Humans are psychologically restricted in the number of "pieces" of information that they can mentally handle at any one time. Interpretive Structural Modeling provides a mental tool for coping with complexity; it bridges the gap between what a person can do unaided and the highly complex problems he or she is called upon to solve, individually or as part of a societal group. Use of ISM in the classroom introduces students to a problem-solving process that is of immediate value in analyzing a particular problem, and which can be helpful, at least in concept, later in adult life when they are faced with other complex issues.

A NEW MENTAL TOOL

In summary, Interpretive Structural Modeling allows the students to share information among themselves about a complex problem or issue and to build a shared understanding of it. They may then critically examine this shared understanding (represented by the model) in light of the facts raised during the modeling session or in subsequent discussion.

II. PLANNING AND CONDUCTING AN INTERPRETIVE STRUCTURAL MODELING EXERCISE

Preparing a Lesson Plan

As for any other significant activity that you undertake with your students, you will want to draw up a lesson plan for the modeling exercise. Figure 2 shows a sample lesson plan that was used for a four-week lesson in a high school World Problems class for juniors and seniors. The topic for this lesson was the effects of world population on the global environment; the overall goal of the lesson was to help the class to understand the environmental aspects of world population growth.

A SAMPLE TOPIC

Your lesson plans will of course be tailored to your own course objectives. Figure 2 is merely intended to show you one way in which planning may be done. The lesson plan is divided into lesson objectives, activities for the students to undertake, and ways to evaluate their learning. In this case, the plan was prepared by a team, including the World Problems teacher, which was experimenting with Interpretive Structural Modeling as an educational tool. The team members found Robert Mager's Preparing Instructional Objectives and Benjamin Bloom's Taxonomy of Educational Objectives: Cognitive Domain very useful. Regardless of the terminology or format that you are accustomed to using, we believe it will be readily apparent that planning to use ISM in your class is no different from the planning you do before using any other method. Planning the lesson simply means that you determine:

A SAMPLE LESSON PLAN

- what you want to accomplish;
- how to achieve it; and
- how to know when you are successful.

Objective	Activities	Evaluation
1. Student will correctly answer X% of questions on knowledge and comprehension of required reading.	Students will be assigned to read articles in Newsweek.	Written test on content of required reading.
2. Student will be able to write a definition of "model" in his own words.	Teacher will introduce class to models in general and ISM in particular through a trivial example.	Test question requesting student to write a definition of "model" and to name some examples.
3. Student will be able to answer yes (/Y) or no (/N) to videoscreen question.	Students will enter class consensus on terminal, as instructed by computer technician.	Teacher's observation of students at terminal.
4. Given a trivial example, student will draw a digraph without computer assistance.	Class will construct a digraph for the example used in class, using computer output.	Given a simplistic example similar, but not identical, to that demonstrated in class, the student will draw a digraph illustrating the given relationship.
5. Given a current world problem or current event, student will identify parts (elements) of the whole (problem) for further study.	Discussion of Third World growth and development (initiated and led by the teacher) will give students practice in identifying elements and examining their influence on the problem of growth and the environment.	In answer to a written test question giving a similar but different world problem, student will list in his own words X% of the elements described.
6. Student will recognize a relationship among elements as distinct from the elements themselves.	Teacher will guide class in selection of appropriate elements, by discussion of elements in general, examples of various elements that could be used, etc.	Given a textual explanation of a real or hypothetical problem and a list of possible elements to model, student will select X% of correct (appropriate) elements, rejecting the irrelevant ones.
7. Student will recognize different kinds of relationships among a group of elements.	Teacher will guide class in selecting appropriate relationship, by discussing relationships in general, examples of various relationships that could be used, etc.	Given a textual explanation of a world problem, including two or more relationships among elements, student will pick out X% of the relationships.
8. Based on what he knows already and new facts and opinions put forth during class discussion, student will evaluate elements two at a time with respect to a given relationship.	Student will answer yes or no to question posed by computer, and defend his choice when challenged by classmates or teacher.	Student will correctly answer yes or no to X% of questions on test similar to those that the computer would pose.
9. Given individual or group actions in one country, student will identify potential environmental consequences outside of that country.	During ISM modeling session, students will discuss such topics. If they do not arise spontaneously as a result of computer-prompted questions, teacher will interject them as appropriate.	Student will correctly answer X% of written test questions on local activities and their global effects.
10. Given a model such as those developed and discussed in class, student will pick out key elements and discuss possible courses of action.	At completion of ISM session when class has structured model, teacher will lead discussion regarding the relative importance of the elements, and class will determine one or more possible courses of action.	In answer to a written test question giving an Interpretive Structural Model, student will select X% of key elements for implementing change and defend those chosen.

Figure 2. Lesson Plan for Modeling Exercise, World Problems Course

Some suggestions and comments on what went into the sample lesson plan may be helpful to others who want to use modeling in the classroom.

Objectives

Bloom and his researchers propose that any educational objectives in the cognitive domain fall into one of six classes.

Knowledge. The student must be able to recall pertinent facts, principles, and theories relative to disciplinary aspects of the problem, e.g., laws of science or ecological principles. It also means knowing what a piece of information means.

Comprehension. The student must be able to recognize these same facts, principles, and theories when they appear in a different context than the one in which they were learned, and he should be able to state them and summarize them in his own words.

Application. In a context new to the student, but similar to others that he has studied before, the student must be able to select the correct facts and principles from the many that he knows, and use them to solve the problem at hand.

Analysis. The student must be able to break down a problem, that is to identify the elements or factors that contribute to it, to recognize their relationships, and to recognize the systematic arrangement of the elements as a consequence of the relationships.

Synthesis. The student must be able to combine the parts of a problem or issue into a whole, showing a pattern or structure not clearly there before. Producing an original composition or a plan, or deriving a generalization or hypothesis are examples of achievement at this level.

Evaluation. The student must be able to make a judgement about something using his own or given criteria. Making comparisons to outside standards or judging the internal logic or consistency of an argument are examples of evaluations a student could be required to make.

The type of learning that can take place during Interpretive Structural Modeling falls into the first four of these classes. Basically, the teacher in this example wanted the students to

- obtain information on particular aspects of world population
- become familiar with modeling in general
- identify the elements of the problem
- examine a relationship among the elements
- create a structural model based on that relationship

This meant that students would move beyond specific knowledge of facts and trends up to the point of analyzing the features of a larger issue (i.e., its elements and relationships).

As Mager recommends, each objective was written in terms of what the students would be expected to do at the end of the lesson, namely, (1) a particular behavior or act, and (2) the conditions under which the behavior is to occur. The point we emphasize here is that objectives are helpful to the extent that they are precise and focused on a particular outcome.

Activities

HOW WILL YOU DO IT?

The activities column lists the specific classroom and homework activities that would prepare students for the modeling and then take them through the exercise. The lesson would conclude with a study of the model's implications. Most of this column of the lesson plan corresponds in general to the activities that are needed for any ISM exercise in the classroom. They refer to both physical activities involving the computer and its output, and the type of discussion that is supposed to occur. As you learn to adapt ISM to your own classroom circumstances, you will come up with variations of these activities; for example, you may at some point want to have individual students working at a terminal developing their own structural models. However, there is a general pattern of activities that remains constant for any ISM exercise: research, specifying elements and a relationship, structuring the model, and examining the results.

Evaluation

The third column in our lesson plan format refers to the evaluation procedures the teacher would follow to determine whether the objectives had in fact been achieved. Note that for <u>each</u> objective, we specified how the evaluation was to be conducted, e.g., written test, observation, or type of question. Where possible, a standard of acceptable performance is also stated. This criterion--how <u>well</u> you want the student to be able to do something--is a point Mager emphasizes strongly. He contends that if you think something is important enough to spend significant time teaching it, there should be a way to evaluate the results. Not surprisingly, this can be the most difficult part of the lesson plan. The one-to-one correspondence of an activity and evaluation method for each objective may help in making this challenging task more manageable.

HOW WILL YOU MEASURE SUCCESS?

Equipment Needed for Interpretive Structural Modeling

Because ISM is essentially a technique for focusing and prompting group discussion, it lends itself most readily to small-sized classes in which discussion plays an important role. However, it can also be used in large classes (up to 40 students), which can model as one group, or split into smaller groups and later reconvene to compare two or more models produced by the small groups. The two most important limits on group size are the number of students you can comfortably lead in discussion without losing their attention, and the number of TV monitors available to you.

SIZE OF GROUP

This raises the question of planning the equipment needed to conduct an ISM session. A telephone jack in the room where the session is to take place is essential. Either a portable telephone ~~or an~~ installed phone in the room can then be used to make the telephone connection to the University of Dayton computer. The receiver rests in the cradle of a portable remote terminal. It is very desirable that the terminal be equipped with a printer to make a hard-copy printout (which is nothing more than a typed sheet), though this is not absolutely necessary.

THE PHYSICAL SET-UP

TV monitors wired to the terminal provide a visual display for the students. Small monitors (12-inch screens) can accommodate no more than 5 students.

Large 22-inch screens, such as may be available from the audio-visual department in your school, can be used for 10 to 15 students. Since you will be standing at the front of the class and the monitors will face toward the students, it is convenient to allow one extra monitor to face you, so you will have no difficulty reading the display.

There must also be cable to connect all the monitors to one another and to the terminal, and enough electrical outlets or extension cords to supply power to each TV monitor. You will need a computer technician to operate the computer. Finally, despite the usefulness of computer technology, a blackboard remains a functional part of the classroom setting, and one should be within arm's reach of you.

The Six Stages of Interpretive Structural Modeling

In this section we describe the basic activities that are part of any Interpretive Structural Modeling exercise. There are six distinct "stages" in an exercise, and the activities are listed here by stage.

1. Orient the Exercise

The purpose of the orientation is to establish clear expectations in your own mind about what the ISM exercise is to entail. You must first define the topic and clarify what you want to accomplish through the modeling. Once you have a general idea of what it is you want to do, start spelling out the details and refine the idea by developing a lesson plan for the modeling exercise. In addition, be sure to give careful consideration to the practical details that must be addressed. How far in advance must you reserve a room and/or equipment? Will students be assigned out-of-class research? How much time should be allotted for the ISM?

The last step in orientation involves acquainting students with modeling. Assuming that the class has been prepared (through study of the topic and perhaps an introduction to models), begin the session by giving the students an overview of what is about to take place. This will establish a context for the remaining activities and help keep attention focused on the model rather than on the technique that you have chosen to use.

The following checklist summarizes points to address during the orientation stage:

a. *Choose a Topic for the Modeling Exercise*

What is the issue or problem being explored by the group? Remember that the broader the issue, the more elements will be needed to adequately represent the topic. You may find it helpful to break a large, complex topic down into smaller, more manageable areas, and then limit the model to one of the more specific areas. What will the model represent?

TOPIC

b. *Establish the Goal(s)*

A goal is a statement describing a broad (abstract) state or condition that you wish your students to achieve. The goal of the exercise should say something about the intended outcomes.

GOALS OF THE EXERCISE

- How will the model be used?
- What do you hope to achieve through the group discussions?
- In short, what are the reasons for having your class create a model?

c. *List Your Instructional Objectives*

The objectives are the statements which describe specific achievements that will indicate when the goal has been attained. Objectives should be measurable and stated in terms of what the students will be able to do at the end of the modeling exercise. These are the instructional objectives you would spell out in your lesson plan for the ISM exercise.

OBJECTIVES

d. *Clarify Roles*

Who will be involved in the exercise? When ISM is used in the classroom there are four distinct roles:

ROLES

- A discussion leader, usually the teacher -- who should oversee the process and guide the content. It is especially important that the leader be familiar with the common ways modeling is used. Like any tool, ISM should be chosen because it best fits a purpose. The leader should be able to help the class create a model that will best illustrate the selected topic. (Refer to Appendix C for notes on leadership during modeling sessions.)
- The group members -- the students, who should be prepared to contribute information and discuss ideas.

- A note-taker -- one who records the group consensus on a prepared form, summarizes, and notes dissenting opinions and changes in definition of elements as they arise. Some preliminary training for the note-taker is advisable and more than one student should be prepared to take notes in each class.

- A computer technician -- who assumes responsibility for operating the computer.

e. *Prepare Students to Build a Model*

FAMILIARITY WITH THE PROCESS

Finally, there should also be time in the orientation to acquaint the students with an overview of the ISM process. This could include:

- an introduction to models in general
- goals of the exercise
- appointing a note-taker
- a review of the activities ahead and how thsy are scheduled to occur
- an introduction to the equipment that will be used

2. Specify the Elements and the Relationship

Both the type of elements and the relationship will depend on the goals of the exercise and how the model is to be used. In this seciton, we outline a sequence of activities that will lead the class to produce an initial element list and relationship for the model.

a. *Familiarize the Students with the Issue under Study*

BACKGROUND STUDY

Usually the content portion of an ISM exercise is provided in previous classwork. Lectures, projects, and individual research can all be used beforehand to prepare the students for the modeling exercise. Then, if the topic has been clearly defined and some guidelines have been established, the students should be ready to specify a reasonable set of relevant elements.

b. *Define the Question that Will Be Used to Generate the Elements*

WHAT TYPE OF ELEMENTS WILL BE USED?

The "generating question" simply provides a way to describe a complex issue in terms of its contributing elements or parts.

For example, if the issue is "overpopulation," a generating question for elements might be: "What are the results of global population growth?" or, if the model is to explore the relationships among causes, the generating question might be: "What factors cause overpopulation?" The generating question, in effect, specifies the type of element that will be used in the model (e.g., outcomes, problems, barriers, causes, factors, effects, etc.)

c. *Define the Relationship that Will Be Used for the Modeling*

The next step is to establish what relationship is most appropriate to the goals of the exercise, and how the model is to be used. In ISM, it is the relationships among elements that determine the structure of the model. The importance of carefully selecting a relationship must not be underestimated.

WHAT RELATIONSHIP WILL BE USED?

Some sample relationships and the models that result are shown in Figure 3.

There are a number of points for you as the teacher to consider in choosing the relationship.

First, the relationship used to structure the model must be transitive. The reason for this has to do with the computer's "ability" to make logical inferences, as explained in Appendix B. For example, a food web is a type of model that shows energy relationships among various biological organisms. If you say that grain provides energy to rodents, and rodents provide energy to hawks, then you are also correct in saying that grain provides energy to hawks. The computer will make this same inference and show the grain connected to rodents and rodents connected to hawks by arrows that represent energy flow. You could not say that rodents eat grain and hawks eat rodents, therefore hawks eat grain. But the computer, brainless thing that it is, will make the inference that hawks eat grain, given the first two pieces of information, because it has no way of knowing that you have not chosen a transitive relationship.

TRANSITIVITY

Once you have selected elements and a relationship, you can easily check transitivity for yourself by substituting a few pairs of elements in the relationship to see if any nonsense inferences will be made by the computer. This check should be made before any computer modeling is begun.

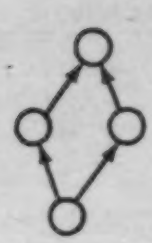
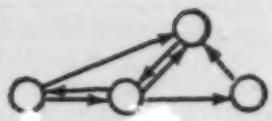
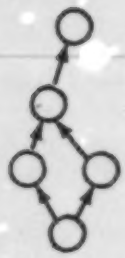
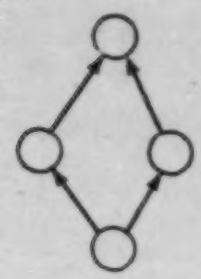
Sample Relationships		Results
* Does ELEMENT A contribute to ELEMENT B?		Elements at the lower level contribute to those above.
* Must ELEMENT A precede ELEMENT B in most cases?		Each level of elements must be achieved before the next higher element is possible.
* Does ELEMENT A influence ELEMENT B in most cases?		Levels may be less apparent, since "influence" is a rather ambiguous relationship.
* Is ELEMENT A more polluting than ELEMENT B?		Levels are distinct since elements are compared and then ranked by measurable criteria.

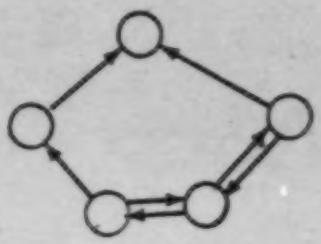
Figure 3. Examples of Relationships to Use in Modeling

HIERARCHY

Secondly, it may be desirable to strive for a relationship that is more hierarchical than cyclical. These two general types may appear as follows:



Hierarchical Model



Cyclical Model

While often realistic, a highly cyclical model may lead to difficulty in interpretation. You may decide, therefore, that a simpler model offers classroom advantages.

TYPE OF RESPONSE

Third, you can use Interpretive Structural Modeling to describe the relationships that make up an existing system (i.e., describe the way things <u>are</u>) or you may want to bring together new ideas and relationships and work them into a new system (i.e., describe the way things <u>should</u> be). For example, you could choose the relationship "Does Element A contribute to Element B?" and pose the question "<u>Does</u> an increase in standard of living contribute to an improved quality of life?" A second model could be made with the relationship based on "should." Using the same pair of elements, the question would read, "<u>Should</u> an increase in standard of living contribute to an improved quality of life?" The class would then have an opportunity to compare and debate the two models.

EXPERIMENT BEFOREHAND

We suggest that the teacher is in the best position to choose which relationship is to be used for the modeling. If you, as the teacher, have established the goals and objectives for the exercise--you, rather than the student, are probably best suited to choose an appropriate relationship. Try experimenting with different types of relationships beforehand to see which topic and relationship best suit the purpose of the lesson. Note too that it is not necessary to employ the computer to test your initial ideas. Try working with a few elements and different relationships and simply draw what you'd expect would result.

d. Generate the Element List

Once you know the type of element and relationship that will be used in the modeling, ask the students to develop a list of elements that together describe what constitutes the issue under study, and meet any criteria established by the group. Your lesson plan should indicate what sources you expect students to use to identify elements and early definitions.

CRITERIA FOR ELEMENTS

Returning to our example of a model of world population, criteria for the elements might be that they:

--are global in nature

--include political, economic, biological, sociological elements, etc.

--are only direct (first order), verifiable or observable results

Sample elements might be:

--decreased food supply per capita

--increased population growth

--increase in world hunger

--increased use of fuels and mineral resources (non-living)

--increased stress and mental disorders

--decreased family stability

Usually, no attempt is made at first to refine or select the elements to be modeled. Simply ask the students to make the elements as specific as possible and to emphasize elements that reflect previous research or class discussion.

REFINE THE LIST

Then, once you have an initial list, it is advisable to go over the list and spend some time revising it. For instance, ask:

- Are the elements clear and precise?
- Are they verifiable? i.e., observable or measurable?
- Does any element unnecessarily "cluster" more than one concept? If so, consider breaking it up into several distinct elements. (For example, "Pollution" as an element may be too broad to

be used consistently; try working with individual elements for "air pollution," "water pollution," etc.)

Prior to the modeling session, you might also want to check the wording of the students' elements and the relationship to make sure the questions that will appear on the screen will be grammatically correct. Grammatical difficulties are distracting; to avoid them, check for consistency between singular or plural subjects and verbs.

e. Organize the Element List

Time constraints will probably preclude using all the elements suggested by the class. One way to organize the element list is to establish a priority among the elements so that elements most valuable to the model are dealt with first. In some cases, you may want to categorize the elements according to some criteria important to the issue. You can then use the categories to discover weaknesses or "holes" in the list of elements; you might also choose representative elements from the categories so that the model reflects a cross-sample of contributing factors. For example, overlooking plants and using only animals in the food web would make the model unrealistic.

ARE SOME ELEMENTS MORE IMPORTANT?

IS THE ELEMENT LIST COMPLETE?

f. Begin Definitions for Elements

The elements should be as specific as possible and the group should strive to agree on the definitions, so that the elements are used consistently throughout the modeling. Because the definitions are so important to the model, you may be tempted to work out rather detailed definitions for the elements before the structuring ever gets underway. This can be unnecessarily time-consuming, however, and in fact, most definitions need to be refined during structuring, anyway, as discussion raises new ideas. Tentative definitions are sufficient at the start, but you should encourage the class throughout the exercise to be creative and more precise in refining the initial element list and definitions.

ABOVE ALL, ELEMENTS MUST BE SPECIFIC

This concludes the activities needed to prepare the elements and relationship that will be used in the model. If your primary emphasis in the modeling exercise is on the learning process, you may choose to spend a substantial portion of time generating the element list and choosing a relationship. If the emphasis is on content, you will probably allot more time to building the model.

3. Structure the Elements with the Relationship

This stage of the modeling involves the computer, and this section will acquaint you with a step-by-step process to follow with your students in developing a structural model. The computer is simply used to collect the class's subjective judgements about the problem under study and then to display the results as a model.

a. *Arrange for the Computer Technology*

TECHNICAL PREPARATIONS

For the modeling sessions, you will need access from the classroom to the computer by way of a terminal, telephone connection and television monitors, as described earlier. In addition to the physical setup, you must also arrange to use one of the ISM programs. The programs are described in Appendix B. Ordinarily you would use the BORDER program in the classroom to create a model and another program, called AMEND, to refine the model.

b. *Develop an Initial Model*

THE DISCUSSION BEGINS

With the terminal, telephone hookup, and television monitors in place, you are ready to begin modeling. During the modeling sessions, the computer prompts the class to systematicall examine the relationships between the elements, by asking a question such as:

As each question appears on the TV monitor, the members of the class discuss their views and arrive at a response by a majority vote. A yes or no vote is recorded at the end of the discussion for each question.

ALLOW ENOUGH TIME

Experience has shown that it always takes longer to model than a beginner might expect. The time required to produce a model is a function of the number of questions that the class must answer, and the number of questions is a function of the number of elements you wish to model. The following figures have been drawn from several different sessions and are representative of the time/element number relationship.

Hours of computer session	Elements in the resulting model
1 1/2	14*
2	12*
3	12
3	19
6	17
6	20

* Models created by secondary students during classroom ISM pilot tests

As the number of elements increases, the number of questions to be answered rises exponentially. If there were only two elements, A and B, there would be only two questions to answer: "Does A relate to B?" and "Does B relate to A?" (The computer is programmed not to ask "Does A relate to A?" and "Does B relate to B?")

But think of the number of possible element pairs in the Presidential chronology example used earlier. This is most easily done by picturing a matrix (which, by the way, is exactly how the computer arrives at the question to be asked for each element pair).

Presidents — Held Office Before	Adams (1)	Hoover (2)	Lincoln (3)	Washington (4)
Adams (1)	X	Yes	Yes	No
Hoover (2)	No	X	No	No
Lincoln (3)	No	Yes	X	No
Washington (4)	Yes	Yes	Yes	X

Note: The mathematical formula for predicting the number of element pairs is (number of elements X number of elements) - number of elements. In this example, (4X4) - 4 = 16 - 4 = 12 pairs.

Here, a maximum of 12 questions must be answered to explore every possible relationship. We have doubled the number of elements from two to four, but increased the number of potential questions by a factor of six.

INFERENCE

You can expect the computer to "infer" some of the relationships, thereby reducing the number of questions to be answered. In addition, when a new element is introduced to the model, the computer automatically calculates the best sequence of questions to ask so that you can examine all the inter-connections in the most efficient way. Figure 4 illustrates the reduction in number of questions made possible by the inferential capabilities of the computer.

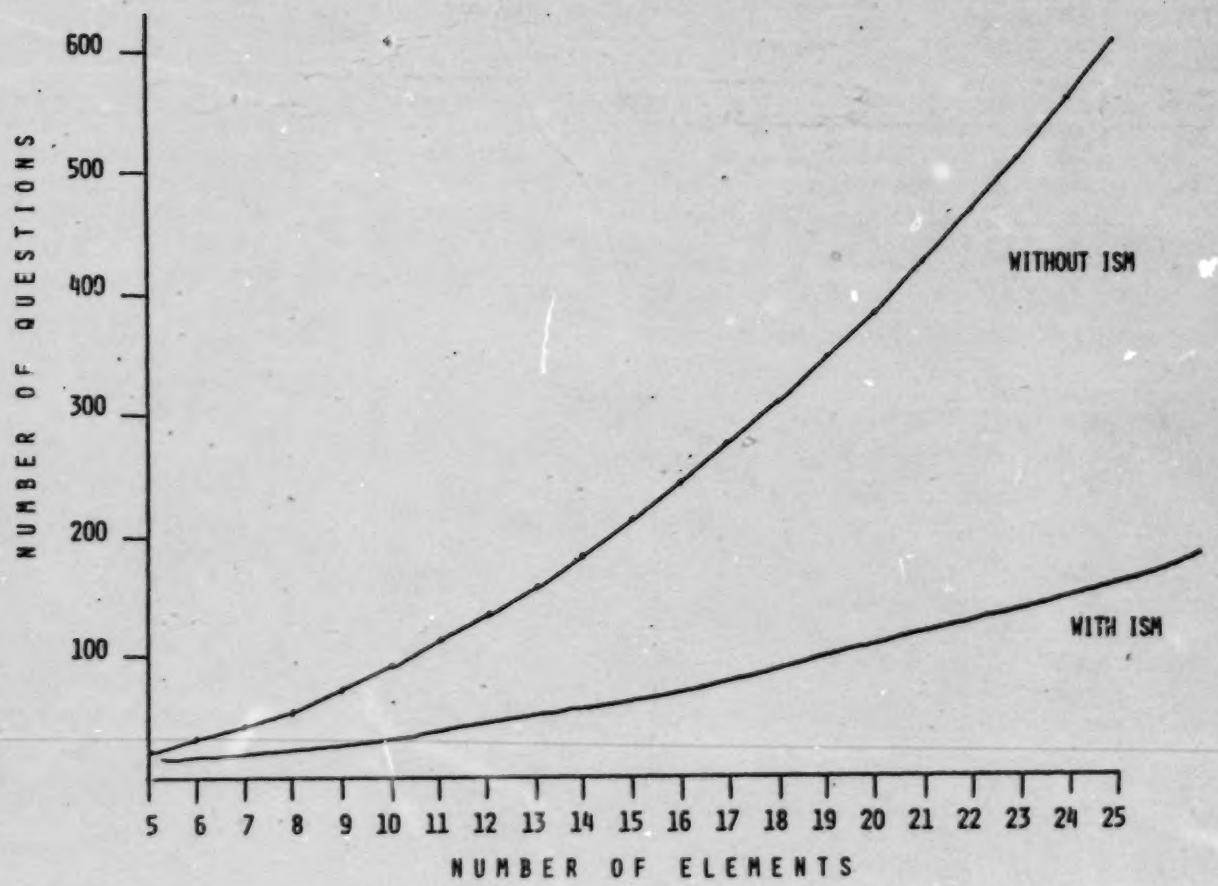


Figure 4. Estimated Number of Questions to Answer

c. *Guide Note-Taking and Discussion*

Your goals and objectives for the modeling exercise will determine what you hope to accomplish through the class discussion. As leader, you will have to strike a balance between overseeing the ISM process itself (e.g., what the computer is doing; how quickly it is responding) and the progress of the discussion. Some points to note:

ISM: A FOCUSED DEBATE

- Let the students discuss each relationship and the elements involved as time permits. Pace the session, but don't miss opportunities to air ideas or make use of background reading students have done on the various topic.
- Seek out input from non-participating class members and try to keep conversation monopolizers in check. One of the strengths of ISM is that it keeps the discussion focused at all times, making it difficult for the participants to stray from the topic. It should also provide an opportunity for all students to contribute to the discussion.
- Keep an eye on the clock and on the computer. Ordinarily the computer will wait 6 minutes for the class' answer to any one question. If you want to pursue a longer discussion, advise the technician.

Note-taking is also an important part of the modeling sessions. Notes on each relationship can be helpful in later reviews of the model, and may point to areas that require further study.

THE NOTES HELP MAINTAIN CONSISTENCY IN THE MODEL

You and the class should agree on element definitions at the outset; however, you will invariably find that other definitions arise during the discussions. The class should be reminded that they are free to make any changes in the list of elements or definitions that they feel are necessary to complete the model. However, careful notes are required to maintain consistency as the discussion continues.

d. *Draw and Examine the First Model*

At certain points, you may stop the sequence of questions and use the computer to display the results of the modeling, from which you may draw a picture of the model.

Returning to the example used in the matrix model, the same four elements and relationships would be shown in a structural model as follows:

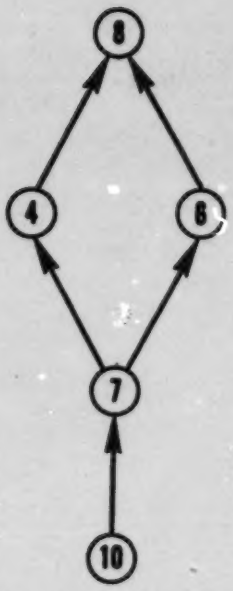
COMPUTER PRINTOUT	PICTORIAL MODEL	DRAWING INSTRUCTIONS
LEVEL NO. 1 8	 	1. Start with Level 1. 2. Write the number of the element in Level 1, and draw a circle around it.
LEVEL NO. 2 4 == 8, 6 == 8,		3. Below the first level element, do the same for the second level elements. 4. Connect the second level to the first by drawing arrows pointing to the upper level.
LEVEL NO. 3 7 == 4,6		5. Write and circle the third level element. Connect it to the elements named in the computer printout, in this case, 4 and 6
LEVEL NO. 4 10 == 7		6. Write and circle the element on the next lower level, and connect it to the appropriate element.

Figure 5. How to Draw an Interpretive Structural Model

HOW TO DRAW THE MODEL

The computer does not actually draw the model, but it prints out the information you need to make the drawing. Figure 5 shows the steps in translating the printed information to a model. The left-hand column is the information exactly as the computer prints it (the element numbers have no special significance here). The center column shows how the model should look. The right-hand column gives step-by-step instructions for using the information in the left-hand column to arrive at the picture in the center.

4. Amend the Structure

Three major activities are required to complete the modeling exercise: Amending, Exploring the Implications of the Model, and Documentation. Although each of these activities is critical to the method's success, we cannot be specific in describing how to carry them out. Your own instructional objectives for the lesson will be the best guide as to how you want to proceed once the class has completed the initial model. You may, for example, want to return to the model later in the year to do follow-up work that incorporates additional content, or perhaps the model is to be used as an introduction to more specific topics. If the modeling method is used at the end of the year to help the students relate all that they have learned, there may be little time for amending.

In this and the following sections, we simply suggest some important points to consider in guiding the students through a study of their model.

In ISM, the final model emerges slowly, as much a result of amending as of the initial structuring process. Often amending will be done both in the classroom and through outside work by the teacher.

Periodically, the class should examine the model for internal consistency and logic, and then amend as necessary. The first model may not be satisfactory -- it may contain relationships that don't exist, or perhaps an absence of relationships which should be there. By this time, the students should realize that the computer has simply maintained a record of what they chose to put into the model. If this record does reveal inconsistencies in thinking, or if parts of the model lack realism or proper emphasis, you can carefully guide the students through some amending procedures that will help them further clarify their own understanding of the topic.

IS THE MODEL CONSISTENT, REALISTIC?

As an example, consider the model of world population produced by a high school World Problems class. (Figure 6). In reviewing the model, the class discovered that there was no arrow from "Increased Poplation" to "Increased demand for social services." Examination of the model revealed that the computer had inferred the relationship through the relationship

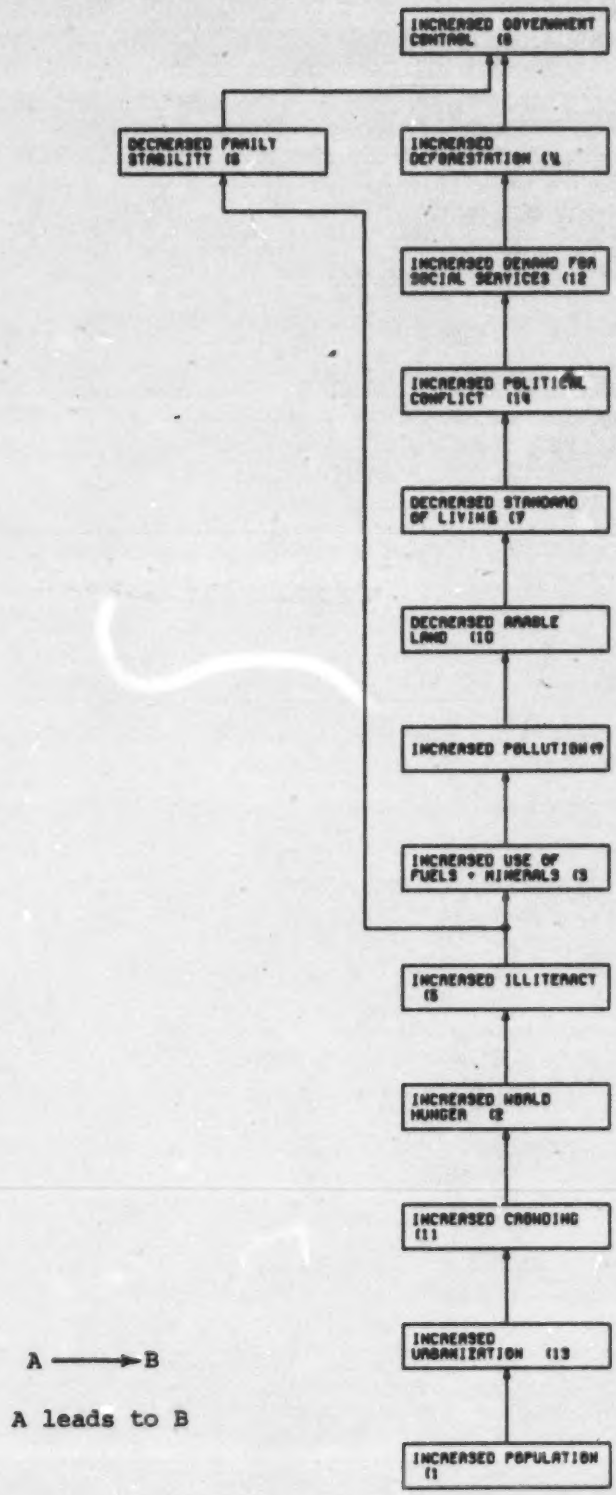


Figure 6. Sample Model: Effects of World Population Growth.

between "Increased population" and "Increase in world hunger," which in turn causes "Increased demand of social services." There is no reason why this arrow cannot be added by the class to indicate the direct relationship as well as the inferred relationship. (However, the computer will "refuse" to show this relationship in the model because to it, it is redundant.)

AMEND BY HAND::.

The special ISM program called "AMEND" is available to make any refinements in the model that the group feels necessary. It is sometimes easier to amend the model by simply removing the questionable element from the model and re-working it through the usual series of questions (with the BORDER routine).

OR USE THE COMPUTER

On the other hand, once you have exceeded a half dozen elements, the model building process starts slowing down and becomes increasingly slower. In the interests of your class' attention span, you have an important option open to you. Remember that the computer is a tool, and it is useful only as long as it helps you make your point. Once you have a small but logical model built, you may want to discontinue using the computer and add elements by hand. The computer-assisted model will still serve its original purpose of stimulating class discussion and focusing their efforts upon a specific issue. When elements are added by hand, they are not subjected to such rigorous analysis as when they are paired by the computer, but that is not to say that you and your class cannot find an appropriate spot in the model to fit them. It is up to you to decide whether your class will benefit more from building a small but precise model using the computer, or a larger, perhaps less exact but more inclusive model, by "eyeballing" the position for additional elements.

USE THE "TOOL" AS LONG AS IT'S HELPFUL

5. Explore the Implications of the Model

By its very nature, structural modeling is exploratory. In other words, the modeling experience can be an opportunity not only for your class to share what they already know about a complex issue, but also to discover new facets of the issue or suggestions as to actions that might resolve the issue. Both the process of creating the model and subsequent reflection on the product should aid your students in the learning process.

After the class is satisfied with the model they have produced, we suggest that you set aside ample time to discuss with them what can be learned from the

UNDERLYING ASSUMPTIONS

model. This might include, for example, discussing the assumptions that are implicit in the model. Perhaps the model is clouded by an inconsistent time frame for the elements. Was a causal relationship, for example, always interpreted in the short-term or in the long-term? Did it make a difference? Can the students discover any evidence of cultural bias? Might another group come up with a different perception of reality? How did the assumptions and perspectives of the students affect this model?

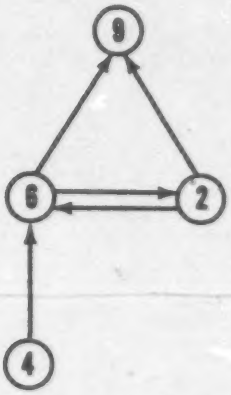
Another way to approach the model would be to identify key points (for example, where the model branches.) If these points can be considered strategic places to intervene, the students could spend some time discussing what persons or institutions might be involved in having the most effect on resolving the issue under study.

ALTERNATIVE ACTIONS

Consider, too, how the model can be helpful in evaluating possible outcomes of alternative actions. Does the model suggest anything about what is right or wrong with our present approaches to the complex problem?

CYCLES

A final suggestion concerns the cycles in the model. Sometimes two or more elements will end up at the same level and be related to each other in a reciprocal way (e.g., elements 6 and 2, as shown below).



In a cycle, every element is related to every other element. Use the cycles to underscore the complexity of the issue the model represents.

To summarize these possible discussion points, we offer this list of suggested questions:

- How can the model be interpreted?
- What was learned?
- What can be said about the assumptions behind the model?
- Does the model suggest any course of action that could help solve the problem?
- Who should be involved in the solution?
- Other ideas?

6. Document the Model

Producing a written documentation of the model is usually the final step in an Interpretive Structural Modeling exercise. The students can document the process and the model for later reference, although the extent to which a model is formally documented will depend on how you intend to use it. Notes on the discussion during the modeling session may suffice.

DOCUMENT AS NECESSARY

An ISM Planning Worksheet

The six stages described above are common to all ISM exercises. For your convenience, we have summarized the major points on a planning worksheet (Appendix C). This worksheet will be useful to you each time you plan a classroom exercise in Interpretive Structural Modeling.

III. RECOMMENDATIONS ON USING ISM IN THE CLASSROOM

In summary, Interpretive Structural Modeling is a computer-assisted modeling method that was originally developed for policy analysis. When it was recognized that the activities that occur during a typical modeling session address several levels of cognitive functioning, namely, knowledge, comprehension, application, and analysis, as set forth by Bloom, it was adapted for experimental use in high school classrooms. The team that pilot-tested the method included the two high school teachers, two university education methods professors, and three researchers familiar with environmental science and the modeling method. The recommendations that follow were made by the team members at the conclusion of the pilot test, and are based upon actual classroom experience with Interpretive Structural Modeling.

MODELING IS EDUCATIONAL

You must first remember that ISM is a tool and not an end in itself. For it to do you and your students any good, you must apply it only to topics that lend themselves to modeling by this method, that is, topics for which component parts and relationships among them can be recognized. The computer's role in the process is to help your students organize their ideas about the components and relationships. You must realize from the outset, and convince the students, that no information will come out of the computer's memory bank that they have not first put in, though it will be in a different form. If they provide false information during the modeling session, they can expect a faulty product.

A TOOL HAS A SPECIAL PURPOSE

This suggests our second recommendation--that every effort be made to encourage your students to criticize and amend their initial models. The point of the entire exercise is that they will acquire new knowledge and insight as a result of the modeling and the accompanying debate. It would be foolish to expect the initial model to reflect these insights.

YOUR FIRST MODEL IS NOT PERFECT

There are several specific reasons why an initial model may look different from what you expected. No matter how clearly you and your class define your elements at the beginning of the session, you will discover that some elements may include two distinct ideas that cause them to be used inconsistently. You may at first think a certain element is too obvious to need a rigorous definition and later discover that this is not the case. The computer may make some surprising inferences from the information provided it. None of these are necessarily "bad," or undesirable because an initial model that looks illogical forces your students to discover where they have used their knowledge illogically or inconsistently.

UNSPOKEN ASSUMPTIONS WILL INFLUENCE YOUR MODEL

The problem with a model may go deeper than inconsistency of definitions, though. It is very likely that your students will make certain assumptions, consciously or unconsciously, in constructing their model. For example, they may be convinced that mankind is facing an environmental crisis, or they may be equally convinced that the future of man is rosy. Experts don't agree on this point; there is no reason to expect a consensus in your class. But clearly, such assumptions will influence a student's approach to model building and thus the model itself. It is your responsibility as teacher and modeling leader to prompt your students to examine their assumptions publicly, so that the things influencing the model can be made explicit.

PLANNING IS CRUCIAL

Our third point is that the most productive modeling sessions are thought out well in advance of the actual computer sessions. Give careful consideration to the number of students that you can comfortably engage in group discussion. If possible, divide your class into halves which will work independently; the comparison between models produced by the two groups will be an excellent starting point for later discussion.

DOWNPLAY THE COMPUTER HARDWARE

Unless your students are accustomed to working with computers, the equipment required for this method is likely to be distracting, at least at first. If you need to meet in a special room (with a telephone jack) for the computer sessions, try to meet there for every class session as well, so as to eliminate the novelty attached to changing rooms.

One way to reduce the distraction caused by computer technology in the classroom is to allow time for a warm-up session using a trivial example (such as the Presidents' chronology problem). Questions about the computer would be answered during this one-day exercise. We found it useful to progress to a fairly simple intermediate model next before undertaking anything as complex as the world population problem. In the Biology class the intermediate model was a food web; in the World Problems class it was a comparison of statistics for democratic, socialistic, and communistic countries. By the time the classes were asked to model a complex issue, they were familiar with the sequence of events and the equipment involved in modeling.

This sequence of models from simple to intermediate to complex was used in the last quarter of a year-long course. In retrospect, one of the teachers suggested that a complex model could be built in increments through the entire year, with additions made at the end of each unit of study. The other teacher proposed that a one-quarter course be devoted to model building and that this be written into the course description. As a continuing exercise, modeling might occupy one day a week, like a lab, with lecture and discussion the other days. If the students are mature enough to work independently, groups of five to ten could produce and document their own models as group projects. The possibilities are as varied as the courses you teach and the topics you cover. However, ISM is not a method that lends itself to speedy or superficial treatment of the topic, so ample time should be alloted for preparation, for the computer sessions, and particularly for discussing and amending the model.

POTENTIAL USES FOR MODELING

In an ISM exercise, the students gain knowledge and comprehension from their individual, directed research on certain aspects of a topic. The model building session focuses on application of the knowlege and analysis of the subject in concert with the other students. The beauty of Interpretive Structural Modeling, then, is that it permits you, the teacher, to attend to both the content and process of education within the context of your course.

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Appendices

A. EXAMPLES OF ISM APPLICATIONS (UNIVERSITY OF DAYTON)

B. HOW DOES A COMPUTER PERFORM INTERPRETIVE STRUCTURAL MODELING?

C. WORKSHEETS AND HANDOUTS

Appendix A

Examples of ISM Applications

(University of Dayton)

1.	Title:	The Design of a Sustainable Human Ecosystem
	User:	Research Team for Strategies for Responsible Development, University of Dayton
	Orienting Question:	What values, principles, and alternative outcomes can help define what ought to be a desirable future for the Sahel?
	No. of Elements:	56
	Relationship Used:	Does the research team believe that --Outcome A-- is a means to --Outcome B-- in most cases?
2.	Title:	A Qualitative Model of the Quality of Rangeland of the Sahelian Ecosystem
	User:	Strategies for Responsible Development, University of Dayton
	Orienting Question:	What are the elements that influence the quality of rangeland in the Sahel?
	No. of Elements:	36
	Relationships Used:	Does an increase in --Element A-- cause an increase in --Element B-- in most cases? Does an increase in --Element A-- cause a decrease in --Element B-- in most cases?
3.	Title:	A System Model for Climax Agriculture
	Users:	Strategies for Responsible Development, University of Dayton Institute for Study and Application of Integrated Development Earth Resources Development Institute
	Orienting Question:	What are the ecological components that are likely to be affected by implementation of interventions based on the climax agriculture philosophy?
	No. of Elements:	27
	Relationship Used:	Does --Outcome A-- lead to --Outcome B-- in most cases?
4.	Title:	Urban Vitality for the City of Dayton (Desirable 10-Year Outcomes)
	User:	Dayton City Commission
	Orienting Question:	What is the system of factors that together describes a desirable state for Dayton in 1986?
	No. of Elements:	60
	Relationship Used:	The creation of --Factor A-- is important in bringing about --Factor B--?
5.	Title:	Economic Viability for the Dayton Area
	User:	Members of the Economic Coalition of Horizon '76, a Dayton Citizen Bicentennial Project
	Orienting Question:	What is the best strategy for the City of Dayton to develop economic viability?
	No. of Elements:	34
	Relationship Used:	Does our group believe that --Outcome A-- is necessary for the realization --Outcome B--?

6.	Title:	Attractiveness of the City of Dayton for Middle Income People
	User:	Task Force appointed by City Commission
	Orienting Question:	How can we reverse the trend of middle income families moving from the city of Dayton?
	No. of Elements:	16
	Relationship Used:	Does a positive change in --Factor A-- bring about a positive change in --Facotr B-- in the city of Dayton?
7.	Title:	Factors of Urban Success
	User:	Kettering Foundation sponsored workshop
	Orienting Questions:	What is meant by "urban success?" What factors of urban life contribute to it?
	No. of Elements:	19
	Relationship Used:	Does the occurrence of --Factor A-- contribute to the occurrence of --Factor B-- in most cases?
8.	Title:	Establishment of a Prototype of Rural Integrated Agricultural Development in Niger ("Projet Tapis Vert")
	User:	Strategies for Responsible Development, University of Dayton
	Orienting Question:	What are the inputs and outputs required to achieve the purposes of "Project Tapis Vert?"
	No. of Elements:	140
	Relationship Used:	Is --Outcome A-- a means that PTV will used to obtain --Outcome B--?

Appendix B

How Does a Computer Perform Interpretive Structural Modeling?

HOW DOES A COMPUTER PERFORM INTERPRETIVE STRUCTURAL MODELING?

Before you can understand how the computer performs Interpretive Structural Modeling, you must know what a computer actually is and how it functions. First of all, a computer is not an intelligent being capable of destroying the earth. Nor is it a box with strings of flashing lights and spinning reels of tape. A computer consists of two basic parts, hardware and software. "Hardware," as the term implies, is something tangible. Circuitry, wires, transistors, memory, etc., make up the hardware of the computer. Some of the same electrical parts which can be found in a color television set are used in a computer.

"Software" is a series of instructions called a program that reside in a computer's memory and which cause the hardware to perform some useful function. Typical functions of a computer are mathematical operations, data storage, searching for items, and data manipulation (such as ISM). Without software, the computer hardware is "dumb" and can perform no useful function. The ISM method has been translated into computer instructions by human computer programmers and therefore can be called a computer program, or software.

The ISM method can be done by hand without a computer. This would be impractical, however, because of the multitude of operations and the possibility of errors. The calculation of an ISM operation which typically takes 15 minutes by hand can be per-

formed by the computer in only fractions of a second with no error.

The ISM computer program utilizes matrices to store and manipulate the answers given during an ISM session. A matrix can be thought of as an orderly array of post office boxes. Each box or cell can be used to hold one piece of information. For the ISM method, the cells of the array contain either a zero (0) or a one (1). A "1" denotes that a relationship exists between two elements or a "yes" answer, while a "0" means that no relationship exists or a "no" answer. An example of a matrix model follows:

Elements

1 = Adams
2 = Hoover
3 = Lincoln
4 = Washington

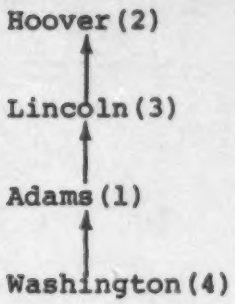
Matrix

	1	2	3	4
1	1	1	1	0
2	0	1	0	0
3	0	1	1	0
4	1	1	1	1

Relationship

Did
Element A
serve as president
before ** Element B***?

The first row of the example matrix refers to element 1 and the question: "Did Adams serve as President before...?". The columns of the first row refer to the other elements in question. Notice for the first row there are "1's" in all of the boxes except for the last one. This zero in the last box means that Adams did <u>not</u> hold office before Washington. The "1's" denote that Adams did serve as President before Hoover and Lincoln. Notice that there is always a "1" for the relationship of the element with itself. The resulting model for the matrix is thus:



Matrices permit large sets of elements and the relationships among them to be displayed in an organized way. Even more important, matrices are susceptible to a variety of operations that allow information to be reorganized by a computer program.

The ISM model described above is trivial and could easily be modeled without the use of the computer. The ISM computer program, however, performs many unseen services during a modeling session. One of these services, and perhaps the most important, is the process of inference. Suppose that you have ten elements to model. In order to fill the entire matrix, 90 questions (10 x 10 - 10 = 90) would have to be answered, which would require a great amount of time. The process of inference reduces the number of questions asked, though the degree of reduction depends on the particular exercise. The process of inference operates as follows.

"Yes" and "no" answers can be inferred. If it was decided that Adams served as president before Lincoln and also Lincoln served as president before Hoover, the computer can infer a "yes" answer to the question "Did Adams serve as President before Hoover?" internally, and would not present that question.

Besides the inference of answers, the ISM computer program also always selects as the next question the one that will permit the most inferences to be drawn.

There are several computer programs that can be used to create Interpretive Structural Models, but the program most commonly used is called BORDER. Its name refers to the process it utilizes in filling in an internal matrix such as the one described earlier in this appendix. BORDER permits you to draw a model after each element has been added to the matrix (that is, after each series of questions on a new element has been completed). BORDER also has a feature called "subordination relation," which eliminates the possibility of cycles and reduces the number of questions to be answered. It is rarely desirable to use the subordination relation, as it is likely to produce an over-simplified model, and we strongly advise you to answer "no" ("N") to the question presented to you by the computer at the beginning of the BORDER program asking "SUBORDINATION RELATION? (Y/N)"

If, by using BORDER, you have created an initial model with cycles in it, you may wish to further clarify the relationships among the elements in the cycle. One way to do this is to assign weights to indicate in which direction the relationship is stronger. The program CYCLE can be used to denote the relative strength of relationships between elements in the cycle.

The program AMEND is used to make changes in a model once you have used BORDER to structure the elements. Two of the

things you can do with AMEND are to add elements to or remove elements from the model.

Anyone who can hunt and peck at a typewriter can do the same at a computer terminal during an ISM session. If you want further information on the computer program options for ISM, you can obtain a user's manual entitled University of Dayton Structural Modeling Software (UD-ISMS Version 1) from the Engineering and Public Policy Group, School of Engineering University of Dayton, Dayton, Ohio 45469.

Appendix C

Worksheets and Handouts

INTERPRETIVE STRUCTURAL MODELING

1. Orient the exercise
   a. Goals and purpose

   b. Roles

   c. Constraints

2. Specify elements and relationship
   a. Familiarize group with subject

   b. Type of element

      Generating question

      Criteria

   c. Relationship

3. Structuring

4. Amending the model
   a. Check for inconsistencies

   b. Add or subtract elements

   c. Examine cycles

5. Explore the implications of the model
   a. How can the model be interpreted?

   b. What was learned?

   c. Determine a course of action that could help solve the problem.

INTRODUCTION TO MODELING

What is a model?

A model is an image or simplified representation of something in the real world.

Every time we describe an object or a situation, we are really constructing a model. A model includes:

1) observation or perceptions about the thing - that is, its parts or features
2) our beliefs about how the parts are related

A model is a simplified version of something. It does not have to include all the details about the thing it represents; instead it includes only those parts that are useful at the time. Therefore, a model makes it easier to think about and work with complicated situations.

Types of Models

1. Mental Models

All of us have mental models about the things around us. A mental model is the "picture" of reality a person has in his or her head.

For example, most people have their own mental "picture" or understanding of something called "the energy crisis." This "picture" could include ideas about

- important things to consider in the energy crisis
- causes and effects of the energy crisis
- how people's lives will be changed
- what people should do about energy

Clearly people's mental models of the energy crisis will be different. Depending on their education and experience, people will think of different parts to the problem and different ways to explain the situation.

Mental models affect our beliefs and our behavior.

Example:

Some problems with mental models are that they:

- may be inaccurate or incomplete
- may be inconsistent
- make it difficult to keep the pieces straight
- are difficult to communicate to others

2. More Formal Models

Mental models are the starting point for all other types of models we might make. Starting with our rough mental "picture," we often find it easier to communicate our ideas by using models built of words, numbers, or even plastic lay-outs, for example.

Formal models also help us overcome a basic human limitation. It is difficult for people to think of many "pieces" of information at the same time. A formal model not only shows you the whole "picture," but also lets you concentrate on just one part of it.

To construct a model, we must first determine the important parts and then organize them the way we think they fit together. This gets our "mental models" out in the open and lets people react to them.

When people build a model together, they have a chance to:

1) share their ideas
2) correct false impressions
3) improve their understanding
4) create a more accurate and useful model of reality.

Usefulness of models

Models can be used to:

1) describe something in terms of its parts and how those parts are organized and related
2) understand how something happens
3) make a complex situation more manageable
4) know more clearly what to expect
5) forecast future situations and to plan for them
6) evaluate the results of actions we might take before we commit ourselves.

By using models, we can save time, money and effort. We can choose the best design without constructing many versions of the real thing.

Example:

A good model improves our understanding of a thing or situation and helps us communicate that knowledge to others.

GUIDELINES FOR LEADERS OF AN INTERPRETIVE STRUCTURAL MODELING EXERCISE

1. Usually the teacher assumes the role of discussion leader for an ISM exercise. This role requires both an understanding of ISM and skills in group process. The teacher's tasks are to:
    a. serve as discussion facilitator, prompting group discussions and interjecting new facts relevant to the debate;
    b. choose the best methods to proceed and when to end the discussions;
    c. provide as much instruction about ISM as the group needs to complete its task, but
    d. not let the group stray from its main purpose of completing a structural model.

2. The class will always be focusing on a question in the form: "Is Element A related to Element B?" Make sure that the students continually focus on the question.

3. The following items should be mentioned at the <u>beginning</u> of the session:
    - The group will be asked to discuss answers to a series of questions which each have one answer - yes or no.
    - To facilitate learning during the discussion, treat your initial answer as a hypothesis, e.g.
      "I believe that the answer is 'yes' for the following reasons..."
    - Since everyone can have a chance to explain his or her opinion, it is important to listen to others' explanations.
    - If there is not a substantial reason for answering "yes" to a question, then you should say "no" -- the purpose of the structuring session is not to justify "yes" answers but to translate our beliefs about relationships into an explicit model.
    - As leader, I (i.e., the teacher) will try to keep the discussion focused on the question we are considering at the time. I will also ask people to share information they have found in their research.
    - Person X is the note-taker for the group. He/she will record our answers to the questions and note important ideas that we have discussed.

- Once I have felt that all opinions on a particular question have been adequately explained and reasonably debated, I will call for a vote. We will accept the majority answer. The note-taker will note the number of "yes" votes and the number of "no" votes. This system of note-taking will allow us to examine minority opinions after the session.

4. It is best not to explain what the computer is doing while conducting a structuring session. Do it either before or after the structuring session.

5. Use conflict to stimulate learning:

   - remind the students that conflict can help produce new insights
   - make sure that you surface minority opinions

6. Encourage students to go beyond answering a simple "yes" to a question; ask them to explain their reasoning to the group.

SAMPLE NOTE FORM

A Note to the Teacher

The form on the following page can be helpful to the note-taker who is responsible for recording important points about the model. This can include, for example, points of disagreement, questions that require further study, definitions for elements, additions of new elements, clarification of the relationship, etc. The purpose of the notes is to document the discussion behind the model and to help maintain a consistency in how the class uses the terms. As the discussion leader, you may want to guide the note-taker by pointing out significant items or comments as they arise during the discussions.

Relationship	Y/N	
4 R 2	Y	- Element 4: limited to North America

Refers to question: "Is Element 4 related to Element 2?"

Record result of majority vote here.

Example of how a term is clarified through discussion.

NOTETAKING OF ISM SESSION

GROUP _____ PAGE _____ OF _____ PAGES

TOPIC _____ DATE OF SESSION _____

Relationship	Y/N	(Notes on discussion, definitions, voting, etc.)	Relationship	Y/N	(Notes on discussion, definitions, voting, etc.)

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GUIDELINES FOR CHOOSING ELEMENTS AND THE RELATIONSHIP

Elements

1. There must be a set of elements or factors which, taken together, describe what constitutes the problem or issue. Some important points to consider in selecting elements are:

   - How large a model is realistic?
   - What type of elements will be used?
   - What methods can be used to produce elements that are as specific as possible?
   - What background reading/research is necessary?

2. The "generating question" results in a list of elements. It specifies the type of element that will be used in the model. To produce a generating question, simply take the issue under study and ask a question that will help the group list the contributing factors. Some examples of different generating questions include:

   What are the { outcomes / problems / barriers / causes / factors / effects, / (etc) } in a given issue?

3. It is important that the elements be as specific as possible. Avoid clustering more than one concept in a single element. If an element is too ambiguous or lends itself to several interpretations, it will be difficult to use it consistently in the model. If the issue is very large and complex, it may be better to focus on a particular area and define the contributing factors as clearly as possible.

4. Ideally, elements would be defined before the modeling gets underway. But more often than not, element definitions are further clarified or even changed during the structuring discussions. This, in fact, is one of the benefits of an ISM exercise - it results in an improved understanding of the factors that contribute to an issue. The important point is that the group strives to be consistent in using the elements.

5. Prioritize the element list so that the most important elements are worked into the model first.

The Relationship

1. The "amount of structure" in a situation refers to:
   a) how well we can describe what constitutes the issue, i.e., the elements
   b) how well we know the relationships among the elements

2. The relationship, then, must be chosen carefully. Some important points to keep in mind are:

   - Transitivity - The relationship used to build the model must be transitive. You can easily check transitivity for yourself by substituting a few pairs of elements in the relationship you are considering.

   - Hierarchy - A more hierarchical model may be more desirable than a cyclical model - it depends on how you want to use the model. In choosing the relationship, consider the type of model that is likely to result.

   - Type of Model - Decide whether the model is to describe what is or what should be, then choose a corresponding relationship (e.g., the present tense versus the future tense or subjunctive mood of a verb).

3. By experimenting beforehand (without the computer) you should find it easier to select the most important relationship for the modeling exercise.